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ABSTRACT

Two fundamental assumptions guide this survey of recent research on anaphora. The first is that anaphoric expressions do not refer to segments in a text or discourse, but to entities that are assumed to be in the language receiver's mind. The second assumption is that a text serves to suggest the referents for anaphora, as does the nonlinguistic context. Topics considered in the review include the types of entities that are possible antecedents in English, the relation of the text to these antecedents, the relation of inference to these antecedents, memory organization, factors that have been posed as influencing anaphora resolution, and the relationships between anaphora and language acquisition. (Author/AA)

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Technical Report No. 31

ANAPHORA: A CROSS DISCIPLINARY SURVEY

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Anaphora: A Cross Disciplinary Survey

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Abstract

Two fundamental assumptions guide this survey of recent research on anaphora. The first is that anaphoric expressions do not refer to segments in a text or discourse, but to entities which are assumed to be in the language receiver's mind. The second assumption is that a text serves to suggest the referents for anaphora, as does the non-linguistic context. As a result, this survey is organized into a consideration of the following questions:

1. what types of entities are possible antecedents in Englisn?
2. wnat is the relation of the text to these antecedents?
3. what is the relation of inference to these antecedents?
4. what does anaphora say about memory organization?
5. what factors have been posed as influencing anaphor resolution?
6. what is known about anaphora and language acquisition?

Introduction

In understanding language understanding, and in particular, reading comprehension, it is almost a truism to say that one cannot stop at the analysis of single sentences alone. In comprehending text, the import of each successive sentence must be determined within, and integrated into, an incrementally growing model of text content and purpose. Now it is also almost a truism that much has been gained already through the formal analyses of sentence-level syntax and semantics that have been put forth in both the context of transformational grammar and that of machine-based natural language question-answering systems (Landsbergen, 1976; Scha, 1976; Winograd, 1972; Woods et al., 1972)

In moving from single sentences to connected text, we need to enlarge our domain of analysis. On what does the connectivity of text draw? What inter-sentential devices carry over to text that most important function of sentence-level syntax which Huggins (in press) describes as "a way of maximizing the rate of transfer of meaning from a language producer (a speaker or writer) to a language receiver (a listener or reader), taking into account the limitations of memory of the receiver". What sorts of knowledge and processing heuristics must be possessed by the language receiver to handle text containing such devices? what would result from their absence?

One such inter-sentential device, anaphora, is the subject of this survey. Anaphoric expressions comprise pronouns,

pro-verbs, some definite noun phrases and ellipses. They epitomize a device for "maximizing the rate of transfer of meaning": for example, one short syllable, "it", has the potential for evoking in the language receiver's mind a complex theoretical construct or an entire chain of events leading to some conclusion,

"It was christened by Feynmann 'the eight-fold way'."
"In the end, it drove Lear mad."

There are two fundamental assumptions about anaphora in which this survey is grounded. The first is that anaphoric expressions do not refer to segments in a text, but to entities which are assumed to be in the language receiver's mind. The second assumption is that a text serves to suggest the referents for anaphora, as does the non-linguistic context. (The latter is discussed at length in an excellent paper by Hankamer and Sag (1976). It will receive only brief mention here.) The result is a model of comprehension in which the relation of antecedent to anaphor is indirect: the text or non-linguistic environment evokes entities in the language receiver's mind which may be addressed, in turn, anaphorically.

(A line is being drawn here between the two notions of anaphora and deixis (Rubin, in press). Deixis, as another linguistic device for pointing to things, shares with anaphora the above-mentioned function of allowing a language producer to maximize the rate of information flow out to a language receiver. However, deictic expressions are seen as pointing to things within the shared spatial and/or temporal context of language

producer and receiver, while anaphoric expressions are seen as pointing to entities in the language receiver's mind. An effect of deictic pointing to "external" things - "You see that chair there?" - may be to engender "internal" entities which may then be addressed anaphorically - "Well, I paid almost $200 for it.")

I see several reasons for discussing anaphora here as an illustration of inter-sentential devices in reading comprehension. First, if a reader does not recognize an expression as anaphoric, or if he or she is unable to handle it as the writer intended, then there is no way that he or she can build up a correct model of the text. Secondly, as recent research in artificial intelligence, psychology, philosophy and linguistics has shown, the process of anaphor resolution may demand very sophisticated syntactic, semantic, pragmatic, inferential and evaluative abilities on the reader's part. Such abilities are even needed to determine what the possible antecedents could be! One might suspect therefore that anaphora might easily be a source of comprehension difficulties. Thirdly, research on anaphora has been very piece-meal (and in rather small pieces, at that) and its observations and results lie scattered through the linguistics, psychology, artificial intelligence and philosophy literatures. There has been no unifying characterization or study of anaphora, and as a result, it is a poorly understood phenomenon. This survey of recent research on anaphora is directed at such a characterization.

There is at least one major topic relevant to anaphora which space limitations preclude my taking up here. That is a survey of

computer-based attempts to handle anaphoric expressions. Such attempts may be found in (Baranofsky, 1970; Burton, 1976; Charniak, 1972, 1973; Deutsch, 1975a, 1975b; Grosz, forthcoming; Hobbs, 1976; Klappholz & Lockman, 1975; Levin, 1975; Norman & Rumelhart, 1975; Rieger, 1974; Rosenberg, 1976; Wilks, 1975; Winograd, 1972; Woods et al., 1972). While these systems are only first- or second-order attempts at modeling anaphoric processing, they do point to real problems that any more sophisticated model must overcome.

Finally, before I begin, there is one point I would like to emphasize. The formal view of language which guides much of this survey on anaphora is not only compatible with other more pragmatic, intention- or belief-oriented points of view (Morgan, in press) but is entirely complementary. To see this, consider the following example: when asked to recommend John Smith for a vacant assistant professorship, his advisor writes "Mr. Smith has a lovely wife". Viewing this sentence pragmatically will assign it an import which damns Mr. Smith with irrelevant praise. On the other hand, viewing it formally will identify those entities that the sentence evokes in the language receiver's mind: namely, the individuals John and John's wife, the description "lovely wife" and "wife", and the predicate "having a lovely wife". All and only these entities are accessible pronominally or elliptically in subsequent sentences, which may of course continue to reflect the writer's beliefs about John Smith. E.g.

Mr. Smith has a lovely wife.

- Moreover, her father attended this university.

or

- Moreover, his brother does too.

or

- His previous one was quite ugly.

A. Antecedents

1. What types of entities are possible antecedents in English?

Probably the most important thing to understand about antecedents is that they are not the elements in the text but are those suggested by it, those concepts being evoked or constructed in the reader's mind. That is, the antecedent of "it" in

1a. Mary gave Sue a T-shirt.
b. She thanked her for it.

is not the string "a T-shirt" but the concept the reader should have of the T-shirt that Mary just gave Sue. To some, this may be an obvious point, but the popular misconception that "a pronoun stands for a noun" indicates that it is not as obvious as one might think. Given this observation, the real question becomes: which concepts that should be evoked or built in the reader's head does the language allow one to reference or re-use? Obviously, not everything is a possible antecedent in English: there is, for example, no anaphor whose antecedent is an adjective, a string of adjectives, an adverb, a preposition, or a quantifier. For example, there is no way to get around saying "all except three" in

2a. All except three boys love their mothers.
b. _____ girls do too.

Researchers have noted many different types of antecedents that English allows. I shall mention several here, in order to

illustrate some of the skills that processing anaphora demands of a reader.

Examples 3 and 4 show two types of antecedents: individual concepts and sets of individuals.

3a. Mary took her nieces to Design Research, where
b. she bought each of the girls a T-shirt.
c. They thanked her for them.

4a. John met Mary and Alice at Logan airport.
b. They took a taxi home.

The antecedent of "she" in 3b. is the explicitly mentioned woman, Mary. On the other hand, each antecedent of "they" (and "them") in 3c. and 4b. is a set of objects. However, the three antecedent sets differ radically with respect to how they come about. In 3c., the antecedent of "they" is the explicitly mentioned set of Mary's nieces, that of "them" is the set of T-shirts, each of which Mary gave to some one of her nieces. This set is not given explicitly but must be derived from one T-shirt per niece and several nieces. The antecedent of "they" in 4b. is the set of John, Mary and Alice, a set which again is not given explicitly in the text but must be constructed. (Notice that if this example were "John didn't meet Mary and Alice at Logan. They took a taxi home.", one wouldn't infer the above set of three people - "they" is probably just Mary and Alice.)

Notice that such individual concepts also include continuous entities (mass concepts), as well as particular quantities of them, as in Examples 5 and 6.

5a. Water constitutes 76% of the earth's surface.

5b. It occurs as a solid in ice bergs, as a gas in the atmosphere, and as a liquid in root beer.

6. When John spilled water on the sofa, the dog licked it up.

In 5b, the antecedent of "it" is the mass concept, water, and in 6, the particular quantity of water that John spilled.

Example 7 shows a third type of antecedent: generic or class concepts.

7a. A German Shepherd bit me yesterday.
b. They are really vicious beasts.

The antecedent of "they" is the generic concept "German Shepherds" which the reader is assumed to be able to derive from the particular one doing the biting. I am asserting that, as a class, they are vicious beasts.

A fourth type of antecedent could be termed functions, since they are similar to the mathematical notion of a procedure which associates a value with its argument(s). A function differs from a traditional "antecedent" in that it is not a particular object to which one is referring, but rather to a way of defining a new object, given a new set of arguments. In Example 8,

8. The man who gives his paycheck to his wife is wiser than the man who gives it to his mistress.

"paycheck" can be thought of as a unary function "paycheck of X", whose argument X ranges over wage-earners and whose value, for a given wage-earner, is a particular paycheck. The antecedent of "it" in this example is the function "paycheck of X", with X now bound to this new kind of man - one who gives his paycheck to his mistress. Such antecedents have been discussed by linguists under the title "pronouns of laziness" (Bartsch, 1976; Edmondson, 1976; Geach, 1962; Karttunen, 1969; Partee, 1972, 1975).

Predicates constitute a fifth type of antecedent, where again the notion of antecedent has to be stretched somewhat. A predicate antecedent is not a specific object or action mentioned previously, but again is a way of defining new ones. Where the antecedent of an anaphoric expression is a predicate, the expression evokes a new object or action, one for which the same predicate is true. A predicate is anything which can be thought of as a property of something or as a relationship between things. Syntactic verb phrases, for example, may be understood as predicates. Predicates may be asserted or questioned as in

John is a doctor.
Did John meet a lama in Nepal?

where the predicate "being a doctor" can be taken to be asserted of John in the first sentence and that of "meeting a lama in Nepal" can be taken to be asked about John in the second. Alternatively, the second sentence can be read as questioning whether the predicate "John meeting a lama in place X" is true of Nepal, or whether the predicate "Y meeting Z in Nepal" is true of John and some lama. That sentences rarely have a single interpretation as to what is being predicated of what is extremely important to anaphoric reference, as will be discussed later.

In addition to being asserted, questioned or even ordered (e.g. "Be a good girl."), predicates may also be used descriptively to specify one or more members of the class the predicate is true of. Consider the phrase

A green tie-dyed T-shirt which Mary bought at DR

There are four simple predicates here - green, tie-dyed, T-shirt and 'which Mary bought at DR' - all of which are true of any object denoted by this phrase. Note that one or more of these simple predicates can be composed into a single complex predicate, such as 'tie-dyed T-shirt', 'green tie-dyed T-shirt', 'T-shirt which Mary bought at DR', etc. Complex predicates, as well as simple ones, can function as antecedents, and again comprehension requires the ability to recognize and manipulate them.

Examples 9,10 and 11 all contain instances of anaphora whose antecedents are predicates.

9a. Mary bought a green tie-dyed T-shirt.
b. Fred bought one too, though he wanted a red one.

10a. I can walk and I can chew gum.
b. Ford can Ø too, but not at the same time.

11a. Garth beats his wife.
b. Fred does Ø too, though she hits him back.

The antecedent of the first "one" in 7b. is the complex predicate 'green tie-dyed T-shirt', which is true of what Fred bought. It is probably not the same T-shirt as the one Mary bought (though that is a pragmatic inference, not one derivable linguistically). The antecedent of the second "one" is the predicate 'tie-dyed T-shirt', from which the more complex predicate 'green tie-dyed T-shirt' has been composed. Because this latter predicate is incompatible with the predicate 'red' which is also true of what Fred bought, it cannot be the antecedent of "one" in this case.

Examples 10 and 11 illustrate ellipsed verb phrases ("null anaphora"), indicated by "Ø". The antecedent of such an anaphor is always a predicate. In example 10, it is the complex predicate 'walk and chew gum'. Note that this predicate was not given explicitly in the text, but had to be derived from the two simple predicates 'walk' and 'talk', which were earlier predicated separately of me. In Example 13, the antecedent of the ellipsed verb phrase is ambiguous: it is either the predicate 'beats his wife', asserting that Fred also beats his own wife, or the predicate 'beats Garth's wife', asserting that the poor woman is doubly put upon. (Discussion of examples similar to these can be found in (Bresnan, 1971; Grinder and Postal, 1971; Partee, 1972; Sag, 1976) under such labels as "sloppy identity" and "identity of sense anaphora".)

Events, actions, and states may also serve as antecedents, as in Examples 12 and 13.

12. John dunked Mary's braids in the inkwell. Because it made her cry, he apologized for doing it.

13. Sam is a male chauvinist, and he's not ashamed to admit it.

In the first example, both the event corresponding to John's dunking Mary's braids in the inkwell (the specific incident that made her cry), as well as the action, dunking Mary's braids in the inkwell (what John apologized for doing), are available antecedents. In Example 13, being a male chauvinist can serve as an antecedent for "it".

Another type of antecedent comprises entities which are introduced contextually through the writer and reader's shared knowledge of the world. For example in

14a. John's room was a mess.
b. Even his sneakers were dangling from the chandelier!

I presume the antecedent of "the chandelier" is the one in John's room. Such context-definite noun phrases are discussed at great length in (Chafe, 1976; Charniak, 1972, 1973; Clark, 1975; Deutsch, 1975a, 1975b; Grosz, forthcoming; Haviland & Clark, 1974; Hobbs, 1976; Klappholz & Lockman, 1975; Rieger, 1974; Rosenberg, 1976).

Finally, as a consequence of the claim that anaphoric expressions refer to entities in the speaker's and listener's minds, there is no need for such entities to exist in any real sense. Thus a hypothetical individual, set, event, etc. may serve as the referent of an anaphoric expression. For example,

15a. John wants to catch a trout for dinner.
b. He plans to eat it with sauteed almonds.

Here the referent of "it" is the trout that John will have if his desire to catch one is fulfilled. Issues of reference and existence are discussed in (Bartsch, 1976; Edmondson, 1976; Karttunen, 1971; Lakoff, 1970; Nash-Webber & Reiter, 1976; Partee, 1972).

To summarize this section, I have presented what I believe to be a partial answer to the relevant question, "What types of entities are possible antecedents in English?". It should be clear now, for example, that pronouns do not just "stand for" nouns, and that just being capable of evoking possible

antecedents for an anaphoric expression presumes complex cognitive abilities on the part of any understander.

2. what is the relationship of the text to these antecedents?

As Hankamer and Sag (1976) point out, it has long been known that certain anaphoric expressions do not require a linguistic antecedent, but can be controlled by some aspect of the non-linguistic environment shared by the speaker and listener. Thus, if I'm eating a mushroom and you say to me, "Do you realize that it's hallucinogenic?", the antecedent of "it" is the mushroom that I am eating, which neither of us has mentioned, but which both of us are aware of. Most often in reading, the writer and the reader have little or no shared non-linguistic environment, so that most anaphoric expressions will have as antecedents entities derived from the text.

In the previous section, I mentioned several different types of antecedent entities - individuals, sets, events, functions, predicates, etc. Obviously not every stretch of text will evoke each type of antecedent, though it is entirely possible for an entity presumably evoked in one way to be reconfigured into an antecedent of another type (See Section A.3). Thus it may not be a profitable question to ask what antecedents can be evoked by a particular piece of text. On the other hand, it is profitable to ask what antecedents can not be evoked by a particular piece of text, and it is to this question that some recent research in linguistics has been addressed.

Kuno (1970) and Karttunen (1971), for example, have pointed out that noun phrases in predicate nominative position do not evoke individual referenceable entities. That is, in example 16a., "he" may only refer to Bert and not "a Maori" (or the Maori that Bert is), while in 16b., "he" may refer to either Bert or the Maori he met yesterday.

16a. Bert is a Maori. He lives in New Zealand.
b. Bert met a Maori yesterday. He lives in New Zealand.

However, both instances of "a Maori" evoke entities which can serve as either generic antecedents (Example 17) or predicate antecedents (Example 18).

17a. Bert is a Maori. They are indigenous to New Zealand.
b. Bert met a Maori yesterday. They are indigenous to New Zealand.
-("they" = the generic class of Maoris)

18a. Bert is a Maori, and Fred is one too.
b. Bert met a Maori yesterday, and Fred met one today.
-("one" = a Maori)

In another paper, Kuno (1975) has also pointed out that no single entity introduced in a noun phrase of "exhaustive listing" may serve as an individual antecedent of a pronoun, though the entity evoked by the entire phrase may. Thus in Example 19,

19a. It was Mary, John and Marsha who flunked Comp. Sci. 112.
b.*He also flunked AM261b.
c. They played bridge every night of the term.

"John", who was introduced in a noun phrase of "exhaustive interpretation" cannot be the antecedent of "he", although the whole group can be the antecedent of "they". (Obviously if John had been introduced earlier in the discourse, as well as being mentioned in this noun phrase, one could refer to him as "he".)

Karttunen (1971) also notes that existential noun phrases do not introduce individual antecedents when they occur in certain negative contexts as in Examples 20 and 21.

20a. Bill doesn't have a car.
b. *It is black.

21a. John failed to find an answer.
b. *It was wrong.

22a. Bill didn't marry a blonde.
b. She had red hair.

Both the simple explicit negative in Example 20 and the implicitly negative verb 'fail' in Example 21 should keep the reader from creating an entity which could serve as an individual antecedent - the car Bill doesn't have or the answer John failed to find. Both existential phrases, of course, could evoke predicate antecedents: that is, 20a. could sensibly be followed by "Frank has one", and 21a., by "Bill made one up." However, a primary problem with negation in English is that it may not be clear from the given sentence just what is being negated, in particular, whether the existential is within the scope of negation. Thus in example 22., the existential noun phrase does introduce an individual antecedent, the female Bill married: what is denied is her blondness, not the existence of such a woman. However, we can not know this from sentence 22a. alone. Only when it becomes necessary to justify a referent for "she" in sentence 22b. is a particular scoping forced on us.

Before concluding this section, I would like to point to one interesting case of textual evocation of referents. Several linguists (Bresnan, 1971; Grinder & Postal, 1971; Hankamer & Sag,

1976; Sag, 1976) have argued convincingly that in the cleanest account of verb phrase ellipsis (Examples 10 & 11 above and 24a below), the verb phrase is present in some underlying syntactic structure and is subsequently deleted. They have pointed out that the deleted material nevertheless seems a potential source of referents for anaphora. This has been called the missing antecedent phenomenon. For example,

23a. Since Fred didn't bake a cake for Mary's birthday, John did Ø.
b. She couldn't eat it though because it was chocolate.

They argue that the first sentence arises from something like

24. Since Fred didn't bake a cake for Mary's birthday, John baked a cake for Mary's birthday.

from which can be derived the missing antecedent for "it" - namely, the cake John baked for Mary's birthday. Since their arguments for a deletion account of verb phrase ellipsis are purely syntactic and do not hinge on missing antecedents, it appears that material deleted before a sentence "reaches the surface" can evoke antecedents as well as material explicitly there.

On the other hand, there are other anaphoric expressions that linguists would like to say actually occur in the original syntactic structure rather than being derived via deletion or substitution of a pro-form. If such anaphora represent, in some sense, material which could give rise to antecedent entities, the question is whether they exhibit the missing antecedent phenomenon as well, and if so, how. Examples like 25 and 26 illustrate the problem.

25a. Although Fred couldn't bake a cake for Mary's birthday, John managed it.
b.?However she couldn't eat it because it was too rich.

26. ?Although Fred didn't sink a boat carrying a gorilla, John sank one, and it drowned.

In (25b), "it" is meant to refer to the cake John baked for Mary's birtnday, and in (26), to the gorilla in the boat that Jonn sank. Neither antecedent is explicit -- they seem rather to come from the material anaphorized as "it" in (25a) and "one" in (26). Since judgments of acceptability vary on such examples, Bresnan (1971) has suggested that those people who accept these examples are actually inferring an antecedent (see Section A.3) rather than being given one linguistically. Whether her explanation is correct or not, it would seem that more than a single mechanism is needed to account for the existence of antecedents.

3. What is the relationship of inference to these antecedents?

In introducing the previous section, I mentioned that certain anaphoric expressions do not require a linguistically introduced antecedent, giving the example of my eating a mushroom and your asking me, "Do you realize it's hallucinogenic?" All such antecedents are available by virtue of being inferable from the non-linguistic environment. What I should like to take up in this section, albeit briefly, is the many instances where the linguistic environment fails to provide an explicit antecedent, so that for one to be available, it must be inferred.

I will be using the term "inference" with respect to antecedents to describe any type of reasoning or manipulative process which can augment the set of available antecedents beyond those which are explicit in the text. Most research in this area has dealt with examples such as 27.

27. John found a shop manual for his Fiat, but the page specifying the dwell angle was missing.

These have shown that inferences embodying general world knowledge about relationships between entities are needed to provide antecedents for definite noun phrases, which out of context would have no unique referent and therefore make no sense. In Example 27, the shop manual John found provides a context in which "the page specifying ..." may denote a unique individual, that is, the page from that shop manual. John's Fiat likewise provides a context in which "the dwell angle" denotes an unique individual - the dwell angle of the distributor shaft of John's Fiat. What this research seems to lead us to conclude is that there is probably no general world knowledge that wouldn't be needed to justify an antecedent for some definite NP.

Since so much has been written about this one class of inferences, often in the context of frames, I shall omit any further discussion of it. (The reader is referred to (Chafe, 1976; Charniak, 1972, 1973; Clark, 1975; Deutsch, 1975a, 1975b; Grosz, forthcoming; Haviland & Clark, 1974; Hobbs, 1976; Klappholz & Lockman, 1975; Rieger, 1974; Rosenberg, 1976). However, there are many other types which should be mentioned in order to show the range of inferential capabilities expected of

any language receiver through the language producer's use of anaphora. (A discussion of some types of inferences needed for resolving anaphora will be given below in Section C.)

In the following discussion, the types of inference mentioned will be presented in order of veracity, ranging from purely structural, always valid inferences to more contingent ones. It is probably the case that the more contingent an inference becomes, the more that judgments on the consequent existence of an antecedent will vary from person to person, that is, judgments on whether a sentence containing an anaphoric expression referring to one of these "antecedents" makes sense. In evaluating reading comprehension, this point might be taken into account, that people might vary as to the amount of effort they will expend inferring an antecedent and how reliable that inference procedure needs to be in order for them to accept its end product as an antecedent. (This discussion is necessarily brief and very informal. For a more rigorous and extensive presentation of material, the reader is referred to (Nash-Webber & Reiter, 1977; Nash-Webber, forthcoming).)

The first set of inferences involve purely structural "re-write" rules, which are independent of the content of the sentence they apply to. One such re-write rule is applicable whenever a non-negative sentence contains an existentially quantified noun phrase within the scope of a universally quantified one, for example,

28a. Mary gave each girl a T-shirt.

In such a circumstance, there will be available as a referent for "tney" or "them", a set of things corresponding to the existentially quantified noun phrase, each of which is linked to one of the things associated with the universally quantified noun phrase, for example,

28b. She bought them at Design Research.

Here "them" refers to the set of T-shirts, each of which Mary gave to some girl. (The qualification that there be no negation around is needed to account for the inapplicability of this rule to sentences like

28c. Mary didn't give each girl a T-shirt.
d. Mary refused to give each girl a T-shirt.

Anotner such inference rule accounts for conjoined predicates as antecedents, where only simple ones have been given explicitly. This rule explains the existence of the predicate 'walk and chew gum', which is the antecedent of the ellipsed verb phrase in Example 10 (repeated here).

10a. I can walk and I can chew gum.
b. Ford can 0 too, but not at the same time.

The reason for mentioning such simple inference rules, when the examples I have given to illustrate them are so obvious to a skilled understander, is to point out that these antecedents are not really explicit and obvious and that reasoning is involved in constructing them. If a reader does not possess or does not apply these inference rules, he will fail to understand anaphoric expressions referring to these antecedents and consequently fail to understand the text.

A third type of inference rule yields generic or class antecedents from a mention of a member of the class, as illustrated in Example 7 earlier (repeated here).

7a. A German Shepherd bit me yesterday.
b. They are really vicious beasts.

It is interesting to note that the only sets which may be inferred in this way are ones denoted by the given lexical items. Thus in Example 7, the only possible antecedent for "they" is the class "German Shepherds" and not "dogs" or "mammals", etc., which are also classes to which a German Shepherd belongs.

To end this section on inference and antecedents, I would like to mention another phenomenon that has been discussed in the linguistics literature (Bresnan, 1971; Lakoff & Ross, 1972; Ross, 1971) and is exemplified in sentences 29 and 30.

29. John became a guitarist because he thought it was a beautiful instrument.
30. Max knifed me before I even realized he had one.

In Example 29, the antecedent of "it" is the guitar (understood generically), and in Example 30, that of "one" is a knife. The simplest account for such examples seems to involve antecedents being somehow evoked by nearby "morphologically related" (Lakoff and Ross' term) lexical items. While Bresnan notes, I think correctly, that such antecedents are inferred rather than grammatically assigned, it is not at all clear just what kinds of inferences and inferred antecedents are acceptable to what people in this circumstance. For example, while it seems possible to infer a "morphologically related" generic antecedent from a given lexical item, it does not seem possible to infer a specific individual one, as in Example 31.

31.*John was a guitarist before he lost it on the subway.

where "it" is meant to refer to John's guitar. Also it does not seem possible to infer an antecedent which is morphologically more complex than the lexical item it is related to, for example

32.*After John lost his guitar on the subway, he gave up being one.

where "one" is meant to stand for "a guitarist".

B. Memory

In Section A.1, I claimed that antecedents are not the elements in a text, but those suggested by it - the concepts evoked in the language receiver's mind. Since anaphoric expressions are capable of accessing those concepts, characterizing aspects of the anaphor-antecedent relation should shed light on the organization of human memory. Conversely any theory purporting to model human memory organization should account for what is known about antecedents and anaphora.

What sorts of things are of concern here? First, consider two entities that are known equally well by the language receiver. In a given state of the text or discourse, it may be the case that one, but not the other, can be referred to pronominally. Consider for example,

33a. I saw your mother at the Led Zeppelin movie last night.
b. She seemed to be enjoying it. *But he looked rather ill.

While "she" is meant to refer to your mother and "he" to your father, the former reference will succeed, whereas the latter will probably fail. This cannot be because your father is unknown or less known to you. To account for this dichotomy, Chafe (1974,

1976) has introduced the notion of consciousness. Only entities which the speaker or writer assumes to be in the consciousness of his addressee can be referred to pronominally (or with diminished stress). (Currently consciousness is described only by the phenomena it is meant to explain, so further research by linguists and psychologists in this area is obviously needed.)

Secondly, consider the following short paragraph.

> 24. While driving through the game reserve, I passed a pregnant zebra, though I almost didn't notice her. Then on past several enormous termite nests and a river full of hippopotami, before I came to our camp. She looked like a distended Moire pattern.

Even after a single intervening sentence, the antecedent of "she" seems difficult to find. To account for this, Chafe attributes consciousness with a limited capacity, with old items being pushed out as new ones come in. For example, my pregnant zebra remained in your consciousness long enough for you to make sense of "I almost didn't notice her", but not long enough possibly for "she looked like a distended Moire pattern". Chafe notes, "the question of what causes the speaker to believe that an item has left the addressee's consciousness needs systematic examination" (Chafe, 1976, p. 32), but speculates that the factors influencing an item's stay include the number of intervening sentences in which it was not mentioned, as well as such discourse boundaries as change of scene. Recent work by Grosz (Deutsch, 1975a, 1975b; Grosz, forthcoming) has shown that in task-oriented dialogues, whose structure closely parallels that of the task being performed, the participants' consciousness of an item is strongly influenced by the task structure. Viewing transcripts of actual

dialogues between an apprentice trying to re-assemble an air compressor and an expert whose advice the apprentice can request, Grosz notes several instances of pronoun references skipping over pieces of dialogue, where in each case, the piece skipped over was a whole segment relating to some distinct subtask or subtasks.

Also substantiating Chafe's speculation that "change of scene" may influence an item's stay in consciousness is a survey of the use of "discourse links" in newspaper articles done by Rosenberg (1976). After charting the thematic structure of several articles from the New York Times, Rosenberg notes that in his sample there were no instances of pronominal reference which crossed thematic boundaries. Even though his sample was small, it is probably the case that such cross-overs really are rare.

There is one more thing I would like to take up before concluding this section on antecedents, anaphora and memory and that is again the problem of missing antecedents. Reconsider Example 26 (repeated below).

26.?Although Fred didn't sink a boat carrying a gorilla, John sank <u>one</u>, and <u>it</u> drowned.

If the question is asked, what did John sink, the answer would be a boat carrying a gorilla. That is, resolving the pronoun "one" indirectly yields a gorilla. Yet many people do not see an appropriate antecedent for "it" in this example. (The boat that John sank may suggest itself, but will be rejected on the grounds that boats don't drown.) That is, these people seem to have in their consciousness a boat, but not a gorilla, even though they

understand the antecedent of "one" to be a boat carrying a gorilla. I don't agree with Bresnan (1971) that this is a case of people's varying capacity to infer an antecedent. I see this as a problem that will be solved when we understand the partner to Chafe's question above. That is, what causes the speaker to believe an item has entered the listener's consciousness in the first place?

C. Anaphor Resolution

Resolving an anaphoric expression, be it a pro-form or a definite noun phrase, refers to the process of determining its intended referent. Many factors have been suggested as influencing a reader or listener's choice of intended referent, more than I can adequately survey in the limited space available. What I shall do instead is present a short piece of text containing several anaphoric expressions and for many, mention factors that have been discussed in the literature as applicable to its correct resolution. In many cases, the examples may not seem to justify, in and of themselves, hypothesizing these factors as an appropriate level of explanation. So interested readers are advised to consult the original sources to discover the range of phenomena each is meant to account for.

35. Fred left his niece at home and went to the zoo with Mary and John.
36. It had not yet opened, so they sat down on the grass outside.
37. Suddenly near John he saw a snake.
38. The girl saw it too, as did John.
39. Fred admired John because he reacted so quickly.
40. John regretted not having a stick, since he could have used it to bash the snake.

One simple factor influencing the choice of an antecedent for "they" in sentence 36, as well as "he" in sentence 37, is that in English, most pronouns are marked for number and gender. So in sentence 36, "they" must refer to something interpretable as a set of more than one item, while in 37, "he" must refer to an animate entity which is not explicitly marked "female". (That "they" is taken to refer to Fred, Mary and John would result from deriving such a set.)

In sentence 37, that "he" refers to Fred and not to John could be explained by the interaction of three factors that have been discussed in the linguistics literature (aside from Fred's being the only other male around). The first is a syntactic constraint blocking John from being the antecedent of "he". This has been rendered in various forms in the literature, the earliest being the "Precede-Command Condition" (PCC), which seems to have been formulated independently by several researchers including Langacker (1966), Postal (1966), and Ross (1967), which wasow (1976) renders as

> Precede-Command Condition: A noun phrase A may serve as the antecedent for a pronoun B (which agrees with A in the relevant features, including person, number and gender) if and only if either
> (a) B follows A in the discourse, or
> (b) A and B are in the same sentence, and B does not command A.

A node X is said to command node Y if every S dominating X dominates Y.

Recently a revised notion of command was offered (Culicover, 1976; Reinhart, 1976), in which it refers to relative depth of embedding. X "C-commands" Y (Reinhart's term) if every left

branching node dominating X dominates Y. The two notions of command differ somewhat in their predictions, although both of them would block "he-John" as a possible anaphor-antecedent pair in 36.

The second and third explanations for Fred's being the antecedent of "he" are based on notions of theme (Kuno, 1976) and a simple cognitive strategy in which the roles of the participants in a discourse are changed as little as possible (Maratsos, 1973). Both would point to the fact that Fred is the subject of sentence 35, the opening sentence of the discourse. A thematic explanation would say that Fred is the theme of the discourse and therefore most easily pronominalizable, being what the reader is most conscious of. The latter, "inertial", explanation would say that since Fred is in the subject role in a previous sentence, the reader will interpret subsequent sentences, if possible, with him in that same role. (One of Maratsos' experiments to show the existence of this strategy is discussed in Section D.)

In sentence 36, that "it" refers to the zoo and not to Fred's home may be explained on semantic grounds, that a zoo is more likely to open than a home. Such semantic selectional restrictions have been used in several computer-based natural language understanding systems in resolving anaphora (Charniak, 1972; Wilks, 1975; Winograd, 1972; Woods et al., 1972).

In sentence 38, "the girl" is understood as referring to Mary, even though two girls have been mentioned, Mary and Fred's niece. Recency - Mary being the last female mentioned - might be

one factor influencing this assignment. But it might also be the case that Chafe's notion of change of scene is at work here; of the two, only Mary participates in the park scene. (Note that the fact that Mary is a girl, rather than say a woman, falls out of the anaphor-antecedent assignment: it is not known a priori. If sentence 34 had been "The woman saw it too", Mary would still have been assumed to be the antecedent, and the fact that she was a woman would have fallen out. This issue of anaphor resolution resulting in a further characterization of a known entity is discussed at length in Rieger (1974).)

In sentence 39, "he" would normally be understood as referring to John. This cannot be the result of syntactic factors or recency because in similar sentences such as

41. Fred phoned John because he needed help.

"he" would probably be understood as referring to Fred. Garvey, Caramazza and Yates (1974) attribute both these choices to a factor that they call implicit causality, which biases the assignment of an antecedent toward the candidate "primarily responsible for instigating the action or state denoted by the antecedent clause". In sentence 39, John would be held responsible for Fred's admiration, while in 41, Fred would be responsible for the phone call. The authors conclude from their experiments that this factor is not an all-or-none thing, but only a bias, which may be attenuated by such other factors as passivization of the antecedent clause (which overtly marks the surface subject noun phrase as the topic of the sentence), negation (which alters the sense of causality), and the relative status of the candidates.

In sentence 40, the antecedent of "it" is the stick John would have in the (set of) possible world(s) in which he had one. That is, "it" refers to a non-existent entity. However, the clause in which "it" occurs may also be understood as referring to that same (set of) possible worlds. (This would not be the case if "it" occurred in a sentence like "He used it to bash the snake", which would require the antecedent of "it" to exist in the current world.) Different possible worlds are associated with different hypothetical contexts (future and modal worlds), as well as different peoples' beliefs and desires. Possible worlds as a factor influencing anaphor-antecedent assignments is discussed in (Karttunen, 1968,1971; Kuno, 1970; Lakoff, 1970).

The above short text does not provide a framework for discussing all of the factors which have been proposed to account for antecedent assignments. Other factors include task-structure in task-oriented dialogues, mentioned earlier in Section B, emphatic stress (Akmajian & Jackendoff, 1970), and empathy (Kuno, 1975, 1976). With all these factors hypothesized as influencing anaphor-antecedent assignments, it is important to note that no one has tried to model how these factors might interact in human anaphor resolution.

D. Skill Acquisition

In the preceding sections, I have noted some knowledge and skills that a competent language understander uses in deriving possible antecedents and resolving anaphoric expressions. What I

will try to do here is review what is known (or believed) about a child's acquisition of these skills and point out some further questions that might be investigated.

First, with respect to antecedents, Huxley (1970), observing the spontaneous speech of two children, age 3-4, noted that "it" seemed to be correctly understood by that age when it referred to an individual inanimate antecedent such as "cup", "table", etc. However, there are several other types of possible antecedents for "it" besides individual count terms, including mass terms (e.g. "milk") and collections of individuals (e.g. "a box of marbles"). A developmental study on the conceptualization of these as antecedents for "it" was carried out by Chipman and de Dardel (1974). They presented children between the ages of 3 and 7 with a display containing a flat cake of clay, a box containing five marbles, a box containing 20 marbles, and a tray containing various size pieces of plasticine chocolate. Then each child was given the four instructions:

1) There is clay there. Give it to me.
2) There is a box with five marbles. Give it to me.
3) There are 20 marbles in the box. Give it to me.
4) There is chocolate there. Give it to me.

At all ages, the children were most successful at responding to the request for clay (a mass term), then the box of five marbles (a small collection of individuals), then the box of 20 marbles (a large collection of individuals), and finally the chocolate (either a mass term or a collection). But even at age 6, where the children's success rate on the clay and the box of 5 marbles was up to 90% (from 30% and 10% respectively, at age 3), their

success rate on the box of 20 marbles was still only 50% and on the chocolate, only 10%! As far as the types of errors the children made, let me quote from Chipman and de Dardel.

> For the clay item, the main error consisted in the children giving a piece of the clay cake which they broke off. For the box of five marbles, the youngest children gave one marble; the children aged 4-5 years gave several but not all marbles; and finally our eldest children (5-6 years) gave all the marbles from the box (but without the box). On the box of 20 marbles item, very few little children gave one marble only: most of them gave several but not all marbles, while our eldest children again gave all the marbles from the box (again without the box). For the chocolate item, the youngest children gave one little piece of chocolate. The children aged 4-5 years gave more than one little piece of chocolate, these being either several of the same type of piece (the smaller rectangles) or several of two different types (the smaller and the larger rectangles). Only two of the 42 subjects ever gave all the chocolate. (Chipman and de Dardel, 1974, pp. 95-96)

Their conclusions center on the child's developing ability to conceptualize either a mass term or a collection of individuals as an individual in its own right, pointing out that it seems to parallel the child's cognitive development in general. I do not know of any research concerned with the other types of antecedents I mentioned earlier, but obviously such work can illuminate our understanding of the child's developing abilities to use and comprehend anaphora correctly.

With respect to the child's growing ability to resolve anaphora correctly, there are at least two relevant studies. One is by Carol Chomsky (1969) on syntactic structure and co-reference, and the other is by Michael Maratsos (1973) on stress and co-reference. As I mentioned in discussing anaphor resolution in Section C., there are cases where the sentence

structure seems to block an otherwise plausible anaphor-antecedent pair. For example, whereas in Example 42a, the pronoun and John may be co-referential (though not necessarily), in Example 42b, such co-reference is blocked.

42a. Knowing that he was going to be late bothered John.
b. Knowing that John was going to be late bothered him.

Chomsky hypothesized that since the rules for non-identity seem to be fairly complex - linguists have spent many years attempting to characterize them - the child would acquire this skill fairly late. Using sentences such as the following,

43a. He found out that Mickey won the race.
b. After he got the candy, Mickey left.
c. Pluto thinks he knows everything.
d. He didn't know why Pluto felt so sad.
e. If he wins the race, Pluto will be very happy.
f. Mickey yawned when he sat down.

Chomsky found that it was not until about 5.6 years that a child learns the notion of a non-coreference restriction on pronouns, as well as selectivity in applying it. This goes against the common assumption that by five a child has mastered the syntax of his native language.

Maratsos (1973) based his research on Akmajian and Jackendoff's (1970) observation that, for adults, "the presence or absence of emphatic stress sometimes has clear effects on the reference of pronouns and other anaphors". So in Example 44,

44. John hit Harry and then Sarah hit him.

if "him" is spoken normally, without stress, adults generally take it as refering to Harry, whereas if it is stressed, John becomes the one to be hit.

Maratsos noted that in his test sentences, the unstressed pronouns could be interpreted using a simple strategy in which the roles of the sentence participants are changed as little as possible: in Example 44 (unstressed), Harry stays the one being hit. In the interpretation which adults adopt in the case of a stressed pronoun, the worm turns and roles are reversed. Maratsos hypothesized that the simple strategy would be acquired early and applied indiscriminately, while the departure from it for stressed pronouns would only come with age and experience with adults. Maratsos tested 106 children, aged 3,4 and 5, having them act out with dolls sentences like 39 above. His results show that all the children are consistently successful with unstressed pronouns, over 85% accuracy. With stressed pronouns, however, accuracy seemed to improve with overall linguistic competence, going from 28% to 81%. Children in the group showing the lowest overall linguistic competence acted out stressed pronouns like unstressed ones 72% of the time. While this is not the only affect of stress on reference (nor the only case of "normal" reference assignments being violated), Maratsos' approach, like that of Chomsky, of hypothesizing a simple cognitive strategy which the child acquires and uses indiscriminately until he learns under what circumstances it must be violated seems to be a valid one which might help to explain problems and retardations in understanding anaphoric expressions.

Conclusion

In this paper I have tried to bring together a variety of ideas on the subject of anaphora. The problems raised by anaphora impinge on several fields. In philosophy, anaphora touches on issues of reference and possible worlds; in psychology, on issues of memory organization and language acquisition; in linguistics, on issues of general syntactic constraints and sentence generation and interpretation; and in artificial intelligence, on the use of diverse sources of knowledge and the control of inferential processing.

I have tried to show that for anaphora to be understood correctly, many different skills may be required, both to derive possible antecedents and to resolve anaphoric expressions against them. These skills would be necessary for understanding spoken language as well as written language, though speech provides additional clues, in the form of stress to aid in resolution. There have been no studies, to my knowledge, of the ease with which readers notice and comprehend anaphoric expressions correctly. I hope this paper will be an impetus to them.

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